Permanent CS Pacing from the Ring of Standard BP Leads

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Summary

The coronary sinus (CS) has been considered as a site for permanent left atrial (LA) pacing for over 20 years although a lead dislocation frequency of more than 10% and high pacing thresholds have been observed. Our two years clinical experience includes 297 patients with permanent CS pacing. In 209 patients with standard BP lead (1-3 tines removed, classic CS group), the lowest acute CS pacing threshold was observed during UP pacing from the ring (ring: 2.26 ± 1.35 V; tip: 4.16 ± 2.76 V). During classic BP pacing, the pacing threshold assumed a value of 2.93 ± 1.85 V. In a second group of 57 patients with split BP biatrial (BiA) inverted hybrid system (anode - RAA UP lead, cathode - ring of BP CS lead) implanted due to recurrent atrial arrhythmias, we found similar values of acute pacing thresholds at implantation during CS ring pacing (2.3 ± 0.8 V). The tip values were significantly higher (5.8 ± 3.5 V) (tines not removed), and the values during BP pacing came to 3.5 ± 2.0 V. Chronic UP pacing thresholds using the CS tip were investigated in the classic CS group by programming UP polarity temporarily. After 1, 2, 3, 4, 5, and 6 months, the respective pacing thresholds at 0.5 ms were 4.2, 4.1, 4.1, 3.9, 3.8, 3.8 V, respectively. Programming of UP polarity in the split BP group allowed for evaluation of the chronic pacing thresholds of the CS ring electrode. The values after 1, 2, 3, 4, 5, and 6 months were 2.2, 2.0, 2.0, 2.1, 1.7, 1.8 V, respectively. We found higher acute pacing impedance values in both groups during UP tip pacing (582 and 593 W) compared to UP ring pacing (286 and 282 W). Mean impedance values after 1, 2, 3, 4, 5, and 6 months were significantly lower during CS ring pacing (289, 275, 322, 328, 349, 337 Ohm, respectively) than during CS tip pacing (548, 584, 612, 611, 616, 628 Ohm, respectively). The study showed the utility of ring electrodes for cathodic CS pacing in the split BP biatrial (hybrid) pacing system. In this system, the distal part of standard CS BP leads including tip and tines are used exclusively for anchoring. The results seem to indicate the direction for permanent CS pacing.

Key Words

Coronary sinus pacing, ring pacing, interatrial pacing, lead polarity, anodic/cathodic pacing

Introduction

Indications for coronary sinus pacing

The development of biatrial pacing by Daubert and coworkers has brought a renaissance of the coronary sinus (CS) as location for left atrial lead implantation. But during the evolution of cardiac pacing, there have been additional indications for permanent coronary sinus pacing which may be grouped into three categories [13,28]: The first category includes various technical reasons that impair the choice of the classical right atrial appendage (RAA) lead position. In patients where stable RAA lead fixation is not possible or where multiple lead dislodgment necessitated a repositioning, the coronary sinus is a valuable alternative. Excessive RA pacing thresholds or poor RA signal quality further encouraged the use of CS leads in particular patients. The second category comprises haemodynamic reasons for coronary sinus pacing: Biatrial pacing using electrodes in the right atrial appendage and coronary sinus respectively helps to prevent pacemaker syndrome of the left heart during DDD pacing in patients with severe interatrial conduction block by avoiding left atrial contraction against closed mitral valve. The aim of pacing therapy in the setting of congestive cardiomyopathy is to improve left ventricular filling by programming an extremely short AV delay. In patients with hypertrophic obstructive cardiomyopathy the short AV delay is used to ensure ventricular pacing and avoid the obstruction. Again, left atrial or biatrial pacing is used to prevent a pacemaker syndrome of the left heart which may develop with a short AV delay. The third category consists in the preventive effect of biatrial pacing with respect to the genesis of atrial arrhythmias in patients with interatrial conduction block.

Historic development of coronary sinus pacing

The first implantation of a coronary sinus lead for permanent left atrial pacing was executed in 1968 by Moss who used a standard bipolar lead [1]. Since then, several groups of investigators pursued different approaches to solve the problems related to permanent coronary sinus pacing [1-28]. The medical literature covers acute and long-term observations of Moss et al. from New York (50 patients) [1-6], Greenberg's group from California (66 patients) [7], Daubert et al. from Rennes (> 50 patients) [8-13], Saksena's team from New York (> 50 patients) [14], and the results from our group at Lublin (>200 patients) [15-22,28,30,32]. Investigations on permanent coronary sinus pacing in smaller patient cohorts are quoted in references [23-25]. It turned out that permanent CS pacing is possible using standard straight bipolar leads [1-7,15-23,28]. However, the quoted studies revealed two main problems: lead dislodgment (3-14%) and exit block (0-16%) requiring re-operation in 5 to 20 % of the patients. The frequency of these problems was similar in all groups. With respect to the frequency of lead dislocation, the different groups report values of 8-9 % [2,6,28], 12 % [17,18,20], 13-14 % [10,12,13]. Reoperation due to exit block was described in 0-2 % [16,19,20,22,28], 5-6 % [6,9,12], 14-16 % [3,7,11]. Bearing in mind that the early experiences were obtained using non-programmable pacemakers, the differences in the reported values are understandable.
The first leads accounting for the particular anatomical situation in the coronary sinus were implanted as early as 1973 [4,6,7]. Greenberg reports: "These leads (Medtronic BP and Cordis UP) were modified from standard leads to accommodate the anatomy of CS by adding a flexible tip that extends beyond the electrode prevents dislodgment when the pacer is retracted by respiratory motion" [7]. The described electrodes were the first CS leads for permanent CS pacing only from the ring (or 2 rings) without classical tip and tines.

Rediscovery of coronary sinus pacing in the nineties

Due to the improved performance of "J" shaped leads, right atrial pacing replaced CS pacing almost entirely during the following 20 years. However, in the early nineties, Daubert and co-workers started again with permanent CS pacing using standard "J" shaped leads [8-11]. Excellent pacing threshold were observed (<0.6 V) due to a close contact of the lead's tip with the proximal or mid part of the coronary sinus wall but the dislocation rate was still high - assuming a value of 16% although the stylets remained in the lead in every third patient. These investigations lead to the development of a special lead with two deflections of 45° in the distal part (Medtronic SP 2188) [22]. The early experiences revealed excellent pacing / sensing characteristics but early lead dislocations were still frequent (13%) [12].

Materials and Methods

Our own experiences date back to 1995, when we started to investigate the coronary sinus as a position for permanent implantation of standard bipolar leads. 209 patients (92 male, 117 female, 11-86 years) were included into the study (classic CS group) for treatment of brady-tachy syndrome (129), AV block (44), sinus node disease (35) and hemodynamic reasons (1). They received single and dual chamber devices for AAI (79) and DDD (82) pacing respectively (confer Figure 1). In the remaining 48 patients, the pacemaker was operated in a biatrial (BiA) mode using the atrial channel with a RA lead and the ventricular channel with a CS lead (confer Figure 2). The AV delay was set to the shortest possible value (15 ms). Table 1 summarizes the different types of operations. As Table 2 shows, we implanted standard straight bipolar leads in the majority of patients. Classical leads with normal tip surface area were preferred because they ensured good contact with the wall of the coronary sinus. In order to further enhance the performance, we removed one to three tines before implantation.
In a second group of 57 patients (26 male, 31 female, 45-78 years) (split BP group), we used a pacing system with a split bipolar configuration for biatrial pacing similar to the one used by Daubert. The term split bipolar pacing was brought up by Barold and Cazeau in their review paper [27]. In our investigations the coronary sinus ring electrode and the right atrial tip

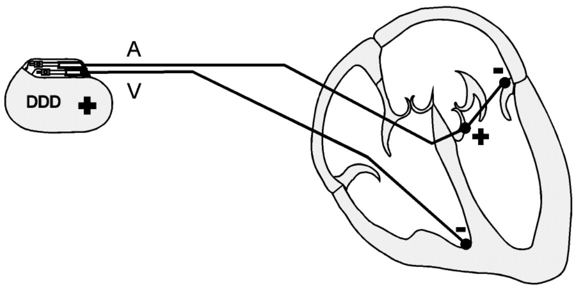

Figure 1. DDD pacing using a coronary sinus lead for atrial pacing and sensing. The coronary sinus lead was connected to the atrial port of a standard dual-chamber pacemaker, and replaced the (usual) right atrial port.

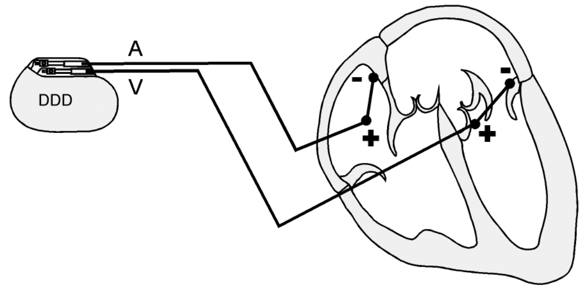

Figure 2. Biatrial pacing system for the classic CS group: The right atrial lead was connected to the atrial port of a standard dual-chamber pacemaker, the coronary sinus lead was connected to the ventricular port (confer also [23,33,34]).

electrode served as cathode and anode respectively, i. e. the we inverted the polarity of the pacing pulse with respect to Daubert's original proposal. The leads were connected to a standard SSI pacemaker or to the atrial port of a dual chamber pacemaker using a Y connector (confer Figure 3). Table 2 summarizes the different lead models that were used.

Results

Acute investigations

After the final fixation of the lead in the optimal position within the coronary sinus, the pacing and sensing parameters were determined. The results for the two groups as measured with the external threshold analyzer ERA 300 (BIOTRONIK) are depicted in

Classic CS group	no.
Pacemaker implantation (AAI, BiA, DDD)	135
Reoperation of patients without CS lead	47
Reoperation of patients with old CS lead	9

Split BP group	no.
Implantation of biatrial pacing system	32
Reoperation of patients without CS lead	7
Reoperation of patients with old CS lead	18

Table 1. Distribution of different types of operation.

Classic CS patient group

- TIR 60 BP: 134 patients
  (tip-area: 6 mm^2, distance tip-ring: 31 mm)
- SD 60 BP: 22 patients
  (tip-area: 5 mm^2, distance tip-ring: 31 mm)
- SX 60 BP: 15 patients
  (tip-area:1.3 mm^2, distance tip-ring: 31 mm)
- TIJ 53 BP: 13 patients
  (tip-area: 6 mm^2, distance tip-ring: 31 mm)
- other: 25 patients

Split BP patient group

- TIR 60 BP: 28 patients
  (tip-area: 6 mm^2, distance tip-ring: 31 mm)
- SX 60 BP: 10 patients
  (tip-area: 1.3 mm^2, distance tip-ring: 31 mm)
- PX 53 BP: 8 patients
  (tip-area: 3.5 mm^2, distance tip-ring: 31 mm)
- other: 11 patients

Table 2. Distribution of implanted leads in the classic CS and split BP groups respectively.

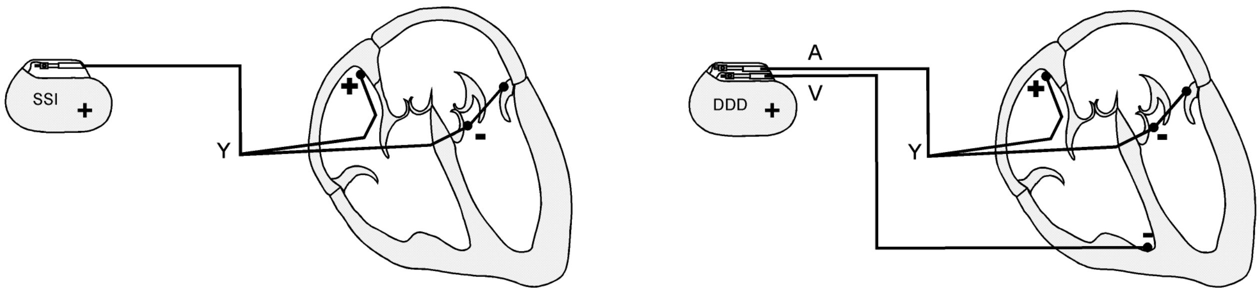

Figure 3. Biatrial pacing systems for the split BP group. By means of a Y connector the CS ring and the RA tip serve as cathode and anode respectively. Note that in our approach the polarity is inverted with respect to the original proposal by Daubert. We showed that it is important to pace in the coronary sinus with a cathodic pulse because the thresholds there are intrinsically high compared to the right atrium [1-13,23,24,26,28] and cathodic pulses are known to be effective at lower voltages than anodic pulses [21,26,27].

Figure 4 and Figure 5. In most patients, the pacing threshold assumed lower values in a mid position, whereas distal positions usually ensured a better stability with respect to lead dislocations. These conflicting findings had to be considered for the choice of the final lead position which underlies all parameter values in this paper. Note, however, that in all patients the unipolar pacing threshold was distinctly lower at the ring in comparison with the tip (confer also [15,16]. Taking the different surface areas into account, the difference of the pacing impedances was not surprising. The signal amplitudes, on the other hand, barely varied in the investigated configurations (confer Figure 4 and Figure 5). Figure 6 shows an example of the signals recorded in the coronary sinus during lead implantation.

Follow-up investigations

After connection of the lead with a standard SSI or DDD pacemaker, the pocket was closed and the pacing mode was programmed. Since unipolar pacing via the electrode ring was not possible for technical reasons in the classic CS group, the polarity in AAI and DDD mode was usually set to bipolar. Follow-up investigations of the pacing and sensing parameters were executed at monthly intervals; they are depicted in Figure 7 and Figure 8 for the classic CS group. The pacing threshold shows a decreasing trend, while the impedance tends to increase.

In the split bipolar configuration group, the left atrial pacing thresholds from the CS ring electrode were evaluated by temporarily programming unipolar pacing. As Figure 9 shows, the respective values are

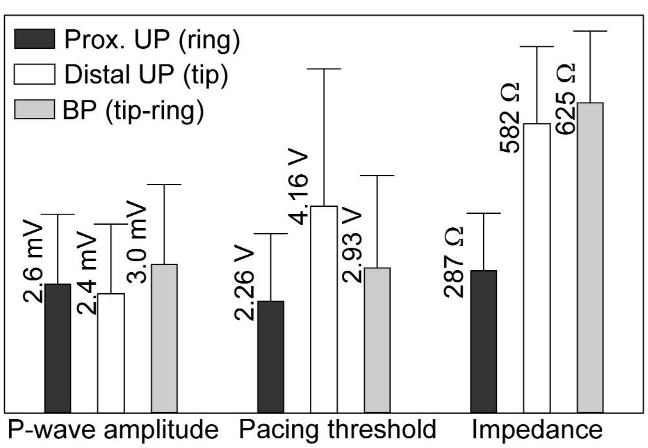

Figure 4. Intraoperative values of left atrial pacing and sensing parameters (classic CS group).

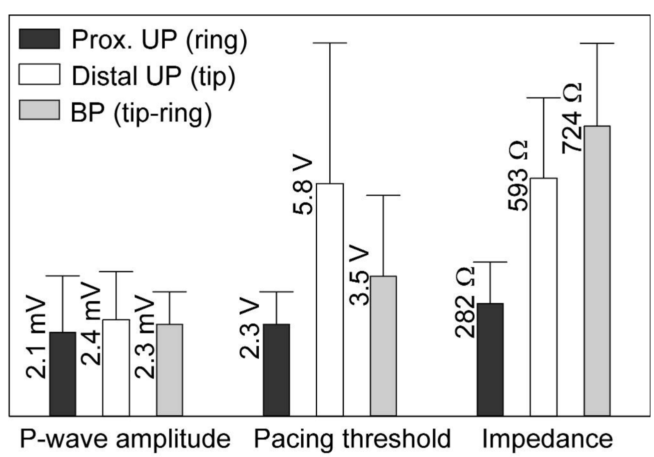

Figure 5. Intraoperative values of left atrial pacing and sensing parameters (split BP group).

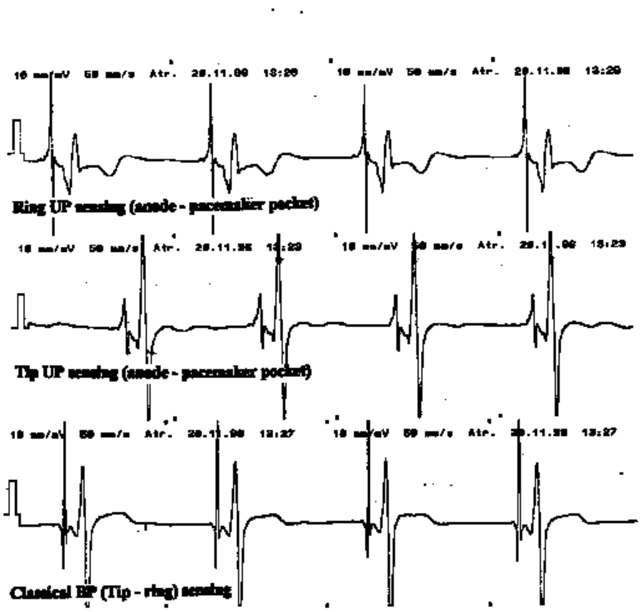

Figure 6. IEGM recording during CS lead implantation using different configurations. Note that a distal position provided increased far-field sensing of ventricular depolarisation.

distinctly lower compared to CS tip pacing (cf. classic CS group results in Figure 7). Figure 8 and Figure 10 reveal that the chronic pacing impedances were similar to the intraoperative measurements in both groups. The lowest values were obtained during UP ring pacing of the left atrium whereas the maximum values emerged during bipolar LA pacing.

The stability of the coronary sinus leads and events

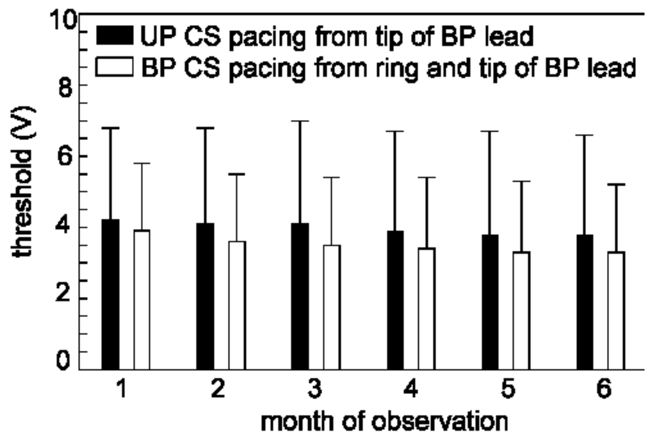

Figure 7. UP CS pacing from tip and BP CS pacing from ring and tip of standard BP lead: LA pacing thresholds during follow-up (classic CS group).

requiring reoperation are summarized in Figure 11. Note the different incidences of lead dislocation of 11 and 4% in the CS classic and spit BP groups, respectively. Since tip pacing was not indicated in the split BP group, the tines were not removed and hence improved the stability of the lead fixation.

For an anecdotal comment on the resynchronising effect of biatrial pacing the reader is referred to Figure 12, Figure 13, and Figure 14 which show intracardiac signals of a patient of the split BP group. The signals have been recorded by the pacemaker and transmitted to the programmer via telemetry. Figure 12 is an example of sinus rhythm demonstrating the slow

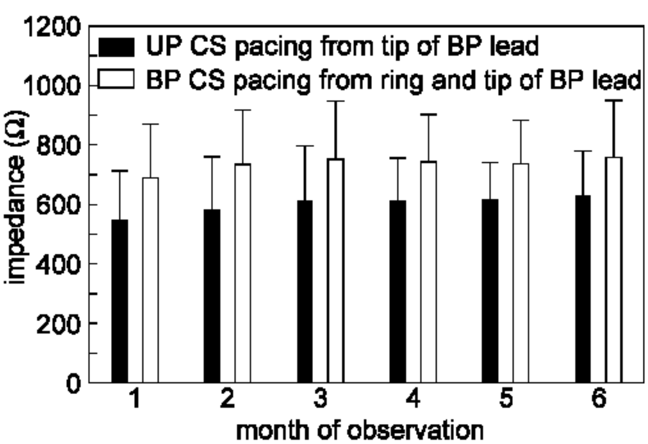

Figure 8. UP CS pacing from tip and BP CS pacing from ring and tip of standard BP lead: pacing impedances during follow-up (classic CS group).

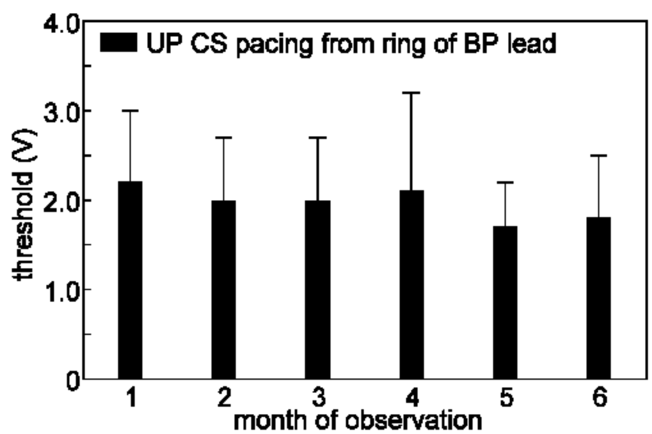

Figure 9. UP CS pacing from ring of BP lead: LA pacing thresholds during follow-up (split BP group).

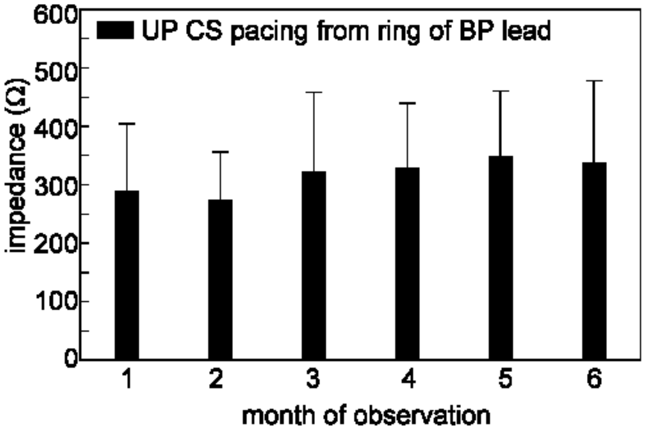

Figure 10. UP CS pacing from ring of BP lead: pacing impedances during follow-up (split BP group).

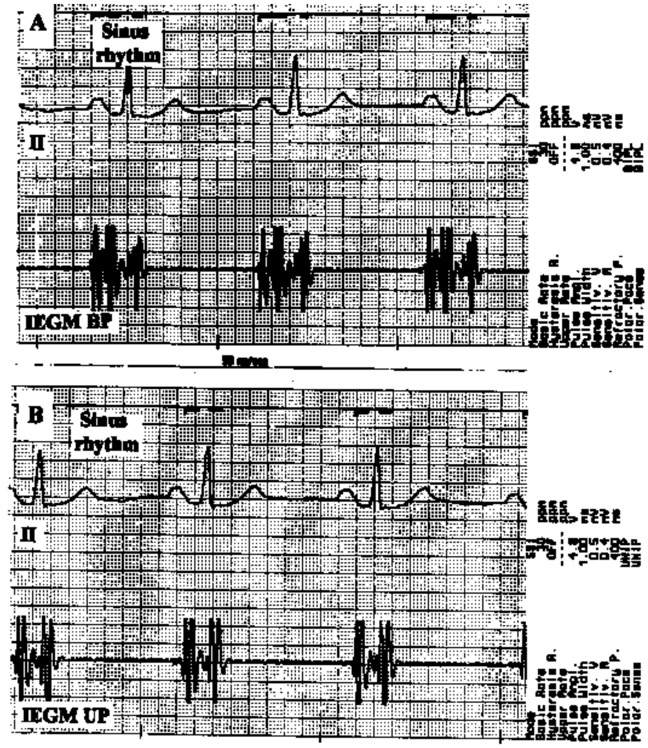

Figure 12. Intracardiac signals during sinus rhythm in a patient from the split BP group. A: Biatrial signals (CS ring vs. RA tip) and surface ECG lead II. Two separate RA and LA P-waves are seen due to severe interatrial block. The total atrial activation time is 190 ms. B: Unipolar signal from the coronary sinus ring.

conduction of the atrial excitation which leads to an increased P-wave duration and increased total atrial atrial activation time (TAAT, defined as the time elapsing between the onset of the P wave in surface ECG lead II and the end of left atrial activation in the intracardiac recording). Figure 13 shows the effect of pacing a single atrial chamber: Neither CS pacing (upper panel) nor RA pacing (bottom panel) do improve the situation with respect to total atrial activation time which still assumes a value of 185 ms. However, during triggered biatrial pacing (AAT, upper panel of Figure 14) or during overdrive biatrial pacing (bottom panel of Figure 14), the total atrial activation time is reduced to 95 ms. Thus, the split bipolar pacing system ensures atrial resynchronisation in patients with interatrial conduction block.

Discussion

Our observation of a lower LA pacing threshold during UP pacing via the ring of the CS lead compared to the tip merits further analysis. A scan of the literature in the field suggests that the observed phenomena may be

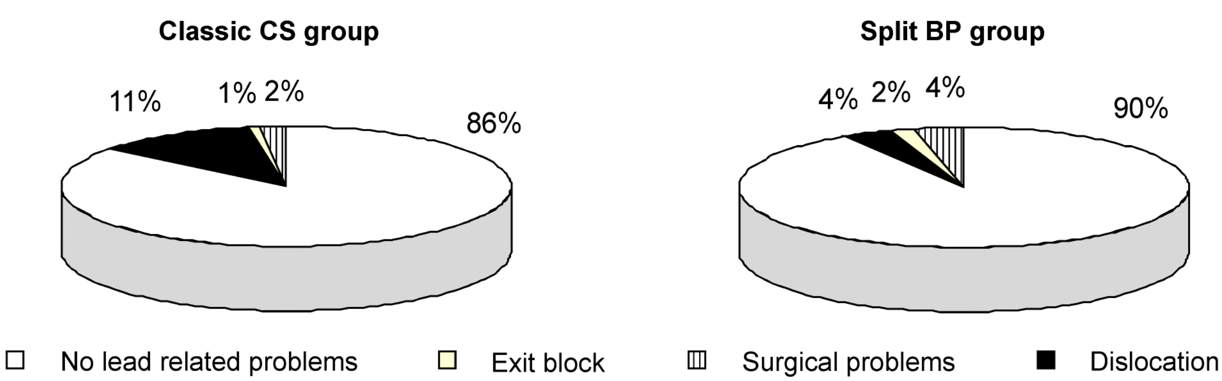

Figure 11. Stability of coronary sinus leads in the classic CS and split BP groups respectively.

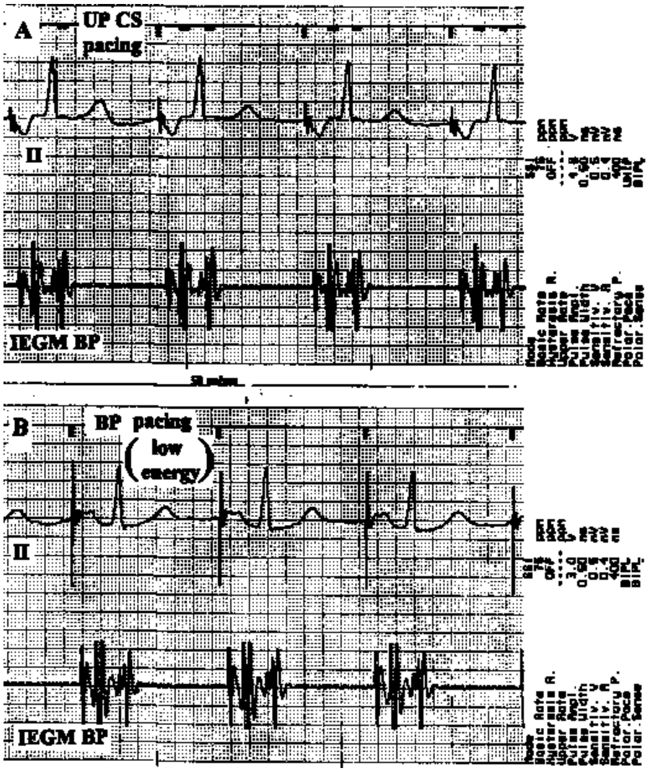

Figure 13. Single atrial pacing. A: If UP pacing is programmed, the pulses are delivered between the CS ring electrode and the pacemaker case. The total atrial activation time maintains an abnormally long value. B: If BP pacing is programmed and the output voltage is chosen too low for left atrial capture, only the right atrium is paced. Again the total atrial activation time duration remains long.

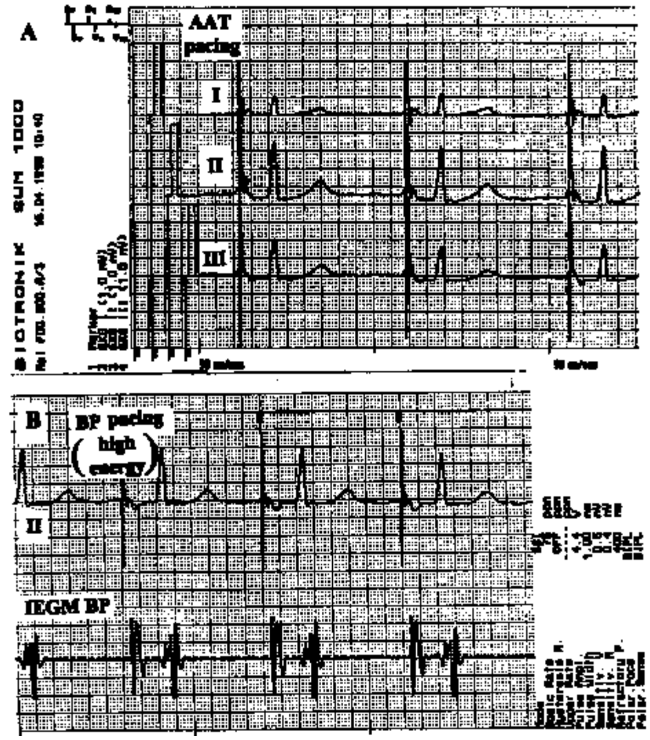

Figure 14. Biatrial pacing shortens the total atrial activation time to a value of 95 ms. A: AAT mode, i. e. an atrial sensed event produces a pulse discharge which leads to LA capture. B: Biatrial pacing above sinus rate.

related to the location of the electrode in different parts of the coronary sinus. Moss and co-workers refer to the proximal coronary sinus as optimal place for permanent left atrial pacing [1-3,6]. Greenberg et al. were the first to explore systematically the influence of the electrode position within the coronary sinus on the pacing threshold in a population of 66 patients using special unipolar and bipolar coronary sinus leads (Cordis and Medtronic respectively). They observed a tendency to lower values near the CS ostium. Lead dislocations occured in 14 % of their patients [7]. These results were confirmed later on by Daubert and collaborators with standard J shaped leads [8-11] and special CS leads (Medtronic SP 2188) [12,13]. Belham also observed that while the proximal coronary sinus is favorable with respect to energy consumption, the position stability may be questionable [25]. Our own investigations support this position: We conclude that using standard bipolar leads for left atrial pacing a compromise has to be found between a low threshold and a stable position.

A scan of the literature in the field reveals two papers that report on the utility of the ring instead of the tip for CS pacing. Moss and collaborators found acceptable LA thresholds during unipolar pacing via the ring electrode in 9 patients [6]. Greenberg et al. investigated CS pacing using the ring of custom made unipolar and bipolar leads (Cordis and Medtronic, respectively). A direct comparison of chronic ring and tip pacing thresholds in the coronary sinus in the very same patient is prevented by technical limitations of currently available pulse generators. However, the thresholds, we determined during reoperation in 18 patients with existing coronary sinus leads, suggest the superiority of CS ring pacing also for chronic applications. This hypothesis is further supported by the comparably low UP pacing thresholds observed during follow-up in the group of patients with split bipolar configurations (cf. Figure 7 and Figure 9). It is important to note that with respect to energy consumption, the pacing impedance has to be taken into account in addition to the threshold. The low pacing impedances of some 300 Ohm observed during unipolar CS ring pacing lead to a rather high energy consumption of around 20 µJ [32]. On the other, the quite high impedance of some 700 Ohm in the split bipolar configuration limits energy consumption due to decreased current flow. In a review of multisite pacing methods of Saksena and Cazeau, it is suggested to connect right and left atrial electrodes to the pacemaker cathodic output in parallel for realization of unipolar cathodic stimulation via both RA and LA leads [27]. However, Limousin recently pointed out that such an approach may even increase the energy consumption, since the pacing impedance is decreased in parallel coupled resistors [26]. In adopting this argumentation and considering our own experiences we therefore prefer the split bipolar configuration for biatrial pacing.

Conclusion

We have shown the feasibility of left atrial pacing from the coronary sinus using standard bipolar leads in more than 200 patients. Our results revealed that the pacing threshold may be minimized by positioning the electrode in the proximal to mid coronary sinus and by using a ring electrode, especially during cathodic pacing. We believe that the energy consumption may be further reduced by reducing the length of the ring. However, the use of standard leads requires a compromise between a low pacing threshold (proximal position of the electrode) and a stable position (deep insertion of the lead). We therefore propose a prolongation of the distal part of the electrode that should be electrically inactive and incorporate longer and softer tines for fixation in a distal cardiac vein. In addition, the user should be free to select the appropriate electrode of a bipolar lead for unipolar cathodic pacing according to the optimal pacing and sensing parameters.

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